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IN THE UNITED STATES PATENT AND TRADE MARKS OFFICE

In re Application of:)
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Nicholas W. Dawes et al)
)
Serial No: 09/599,963)

Filed On: June 23, 2000)
)
For: METHOD FOR DETERMINING THE DELAY AND JITTER IN COMMUNICATION BETWEEN OBJECTS IN A CONNECTED NETWORK)

Claim for Priority Under 35 USC 119

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The Commissioner of Patents
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Dear Sir:

If any charges or fees must be paid in connection with the following communication, they may be paid out of deposit account No. 16-0600.

Enclosed is a copy of the corresponding Canadian application 2,290,016 and Canadian application No. 2,307,911, certified by the Canadian Patent Office and submitted herewith pursuant to 35 USC 119 and by the International Convention for Protection of Industrial Properties and by similar treaties.

Respectfully submitted

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Canadian Patent Office

Certification

This is to certify that the documents attached hereto and identified below are true copies of the documents on file in the Patent Office.

Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,290,016**, on November 18, 1999, by **NICHOLAS W. DAWES, MICHAEL SLAVITCH AND ARVIND RAMASWAMY**, for "Method for Determining the Delay and Jitter in Communication Between Objects in a Connected Network".

Agent certificateur/Certifying Officer

June 27, 2000

Date

ABSTRACT

A method of analyzing the delay and jitter in a communication network is presented. The method is applicable to all networks and is determined as shown by the following equations :

$$D(A,B,t) = | (R(K,B,t) - R(K,A,t) | / 2 \qquad \ldots (a)$$

$$J(A,C,t) = \text{variance in } D(A,C,t) \qquad \ldots (b)$$

where D(A,B,t) : the delay in sending a signal from device A to device B at time t measured at the time of sending the signal to A.

R(K,A,t) : the round trip time for a signal to be sent to A from a standard reference point K and a corresponding signal to be returned from A to K at time t measured at the time of sending the signal to A from K.

J(A,C,t) : the jitter in D(A,C,t) computed over the previous 'M' samples.

Based on measurements taken from a standard reference point K, the delay and jitter between pairs, A and B (where A and B may both be different from K), of devices in the network can be computed. This information is of vital importance in certain applications where one needs to maintain a certain level of communication service over a period of time if the quality of service varies with delay and/or jitter. This method can also help a network administrator in determining the suitability of a network for such services.

METHOD FOR DETERMINING THE DELAY AND JITTER IN COMMUNICATION BETWEEN OBJECTS IN A CONNECTED NETWORK

Field of the Invention

This method determines the delay and jitter in communications between a pair of devices in a network. It assumes the prior knowledge of the topology of the network. This method is applicable to services which make use of a communications network and require some measurements of the service provided by the network.

References

[1]. Method of determining the topology of a network of objects - US Patent # 5,933,416

[2]. Method of determining the topology of a network of objects which compares the similarity of traffic sequences/volumes of a pair of devices - US Patent # 5,926,462

Background to the Invention

A communications network is increasingly becoming the foundation upon which many applications and services are built. The classic example of such a popular communications network is the Internet upon which, among other things, a whole new field of business termed e-commerce is based. Even within a local environment, a communications network is used for applications such as electronic mail for the dissemination of information within an organization. The quality of applications and services running over these networks are dependant on the quality of service provided by the underlying networks. This creates a need for automatic methods of measuring a network's quality. One such measure of the quality of a network is the delay in communication between a pair of devices in the network. Another measure, the computation of which is described in this invention, is jitter which measures the variation of this delay. Depending on the application, either delay measurements or jitter measurements or both may be of interest. For example, in Voice over IP applications, not only is delay of importance but also the jitter in the network, i.e., two users communicating by voice over the network should not experience a lag in communication and should not experience abrupt pauses in their conversation either. The measurements described in this invention can be used by a network administrator who is interested in evaluating or monitoring a network to ensure it meets the criteria for the deployment of an application over the network.

The delay and jitter computation described in this invention make use of knowledge about the physical topology of the network which could be obtained by methods described by Dawes et al in [1] and[2].

Summary of the Invention

A method for determining the topology of a communications network has been described by Dawes et al in [1] and [2]. Such topology information is made use of in determining the delay and jitter between an arbitrary pair of devices in the network. A standard reference point is chosen from which all measurements are made.

Let $R(K,A,t)$ be the round trip delay from the reference point K to an device A.

For the sake of simplicity, let us assume that delays are symmetric, i.e., that the delay from an device K to an device A is the same as the delay from device A to device K. Although this assumption may not be valid in many cases, it leads to an estimate of jitter which is 50% off in the worst case. This level of accuracy is often acceptable in applications where the order of magnitude of a measurement is more important than the exact value of the measurement.

Let $D(K,A,t) = D(A,K,t)$

where $D(K,A,t)$ is the delay between a signal entering device K directed towards device A and the same signal arriving at A. The delay $D(K,A,t)$ is therefore the sum of the delays in the signal entering A, crossing A, being transmitted along the path from A to B and starting to enter B.

From the above assumption,

$$D(K,A,t) = R(K,A,t) / 2$$

Now let there exist an device B in the network such that device A lies on the path from K to B,

$$
\begin{aligned}
& D(K,B,t) = D(K,A,t) + D(A,B,t) \\
\text{i.e.}\quad & D(A,B,t) = D(K,B,t) - D(K,A,t) \\
& \qquad = (\ R(K,B,t) - R(K,A,t)\ )\ /\ 2
\end{aligned}
$$

If the path from A to C leads through B,

$$D(A,C,t) = D(A,B,t) + D(B,C,t)$$

Thus, we can find the delay between a pair of devices A and C based on measurements taken from a reference point K.

Given a delay computation, either computed as shown above or obtained through other means, we can compute jitter J(A,C,t) over M samples of D(A,C,t). When M = 2,

$$J(A,C,t) = |\ D(A,C,t1) - D(A,C,t2)\ |\ /\ 2$$

where the jitter J(A,C,t) is defined as the variance of D(A,C,t) over M samples.

Finally,

$$J(A,C,t) = J(A,B,t) + J(B,C,t)$$

Example :

Given the topology in figure (1), where K is the reference point (referred to as the NMC from now on) and where we want to compute the delay and the jitter in the communications path A - D.

Let the NMC (K) send signals to A, B, C and D at times t and get the following round trip values (all in milliseconds).

	time t1	time t2	
R(K,A,t1) =	9.2	9.8	milliseconds
R(K,B,t1) =	7.6	6.8	milliseconds
R(K,C,t1) =	3.4	3.2	milliseconds
R(K,D,t1) =	4.6	4.8	milliseconds

then :

$$
\begin{aligned}
D(B,A,t1) &= (9.2 - 7.6)\ /\ 2 = 0.8 \text{ ms} \\
D(C,B,t1) &= (7.6 - 3.4)\ /\ 2 = 2.1 \text{ ms} \\
D(C,D,t1) &= (4.6 - 3.4)\ /\ 2 = 0.5 \text{ ms}
\end{aligned}
$$

$$
\begin{aligned}
D(A,D,t1) &= D(B,A,t1) + D(B,C,t1) + D(C,D,t1) \\
&= 0.8 + 2.1 + 0.5 \\
&= 3.4 \text{ ms}
\end{aligned}
$$

$$
\begin{aligned}
D(B,A,t2) &= (9.8 - 6.8)\ /\ 2 = 1.5 \text{ ms} \\
D(C,B,t2) &= (6.8 - 3.2)\ /\ 2 = 1.8 \text{ ms} \\
D(C,D,t2) &= (4.8 - 3.2)\ /\ 2 = 0.8 \text{ ms}
\end{aligned}
$$

$$
\begin{aligned}
D(A,D,t2) &= D(B,A,tw) + D(B,C,t2) + D(C,D,t2) \\
&= 1.5 + 1.8 + 0.8 \\
&= 4.1 \text{ ms}
\end{aligned}
$$

We can now estimate jitter in the path A-D as

$J(A,D,t2) = (4.1 - 3.4) / 2 = 0.35$ ms

Definitions

signal : a ping or SNMP poll or their equivalent which when sent from an device A to device B should result in a corresponding reply signal being sent from device B to device A, where the corresponding reply signal need not be similar to the original signal received by B.

Round trip time R(A,B,t): The total time elapsed since device A sends a signal to device B at time t, until it receives a corresponding signal from B where the corresponding signal is sent by B only after the receipt of the original signal from A.

Delay D(A,B,t) : The delay between a signal entering device A directed towards B and the same signal arriving at B. The delay D(A,B,t) is therefore the sum of the delays in the signal entering A, crossing A, being transmitted along the path from A to B and starting to enter B.

Jitter J(A,B,t) : Random variation in D(A,B,t) over a period.

Communication network : A set of devices and connections between them that allow the flow of information from one device to an other.

SNMP : An abbreviation for Simple Network Management Protocol. It is a protocol used to communicate with agents on network devices that provide access to information about the device.

NMC : The standard reference point used for all measurements. It is the device on the network on which the software processes implementing this invention reside.

Brief Introduction to the Drawings

A better understanding of the invention will be obtained by considering the detailed description below, with reference to the following drawings, in which:

Figure 1 is an illustration of a portion of a network, and
Figure 2 is a block diagram of a structure for supplementing the invention.

Detailed Description

The method described below is general, is independent of the type of device and does not require an device to respond to SNMP queries.

The software executing the method runs as a software module within the same main software process (referred to as Ariadne) residing on the NMC that executes the methods described in patents [1][2]. Ariadne receives information about the devices in the network from another software process, Hydra, which periodically gathers information directly from the devices in the network. Ariadne uses this information to construct the physical topology of the network. Another software module is used to periodically send signals to the devices in the network and very accurately records the associated round trip delays. The signal used here is the 'ping' operation which does not go against the assumptions made earlier about the processing time of the operation being negligible (or constant) with respect to the transmission times over the network between K and the device. This information is passed on to Ariadne which uses it in conjunction with the physical topology of the network to compute delays on an device as described in this invention. For every device A being monitored, Ariadne computes delays D(A,B) and D(C,A) where B and C are devices that are directly connected to A. i.e., if a graph is used to represent the topology of the network where nodes represent devices and edges represent direct physical connections between devices, B and C would be adjacent nodes to A with edges between B and A and C and A.

D(A,B) and D(C,A) are computed for every device A being monitored by the main software process. These calculations are stored in an internal device database as well as a statistical database. The internal device database stores the most recent D(A,B) values for a device whereas the statistical database stores the history of D(A,B) values over a period of time. Average D(A,B) values for 5-minute and 1-hour intervals over the previous two days and 1-day intervals for older samples are stored in the statistical database.

Once sufficient samples of D(A,B) are gathered, the jitter J(A,B) is computed and also stored in the two databases as described above for D(A,B). These values of J(A,B) and D(A,B) are read in by another software process and used to produce reports. These values are also used to generate alarms based on comparisons with user-specified alarm thresholds for these values. A method for graphically displaying these values also exists wherein for a certain threshold, all points in the network where the jitter and delay exceed the threshold are highlighted in a certain colour (eg. red) on a graphical map displaying the topology of the network. The user can change thresholds and at a glance see the non-conforming portions of his network.

In addition to this, a software process provides an interface for a user to specify two devices A and B (not necessarily connected directly to each other) over which the user would like to see delays D(A,B) and jitters J(A,B) computed and alarmed. This is very useful in identifying the total delay and jitter experienced by a user on device A who is sending signals to device B. Since applications usually specify minimum requirements for acceptable service in terms of the end nodes involved in the application, the above calculation becomes essential.

CLAIMS
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1. A method of analysing a communication network comprising:

determining the mean transit delay between the entry of a signal into a device X and the entry into a device Y by polling each device from a network management computer (NMC) which is in communication with the network, and processing signals in the NMC to determine a transit delay D(X,Y) in accordance with the process:

$$D(X,Y) = | R(NMC,X) - R(NMC,Y) | / 2$$

where

R(NMC,A) is the round trip time to send a signal from the NMC to A and receive the response to that signal back at A

and where X and Y are directly or indirectly connected.

2: A method of determining the jitter or variance in the mean transit delay between the entry into a device A and the entry into a device B by repeatedly determining that mean transit delay and determining the variance in that mean transit delay over a set of measurements.

3: A method of determining the end to end delay between two devices A and B as the sum of the delays in the individual steps between A and B, where the device A may or may not lie on the path of signals from the NMC to B and the device B may or may not lie on the path of signals from the NMC to A.

4:A method of determining the end to end jitter between two devices A and B as the sum of the jitters in the individual steps between A and B, where the device A may or may not lie on the path of signals from the NMC to B and the device B may or may not lie on the path of signals from the NMC to A.

5: A method of determining the end to end delay experienced by a user of a device A communicating with a device B as defined in claim 3 and the path between A and B is determined by knowing the topology of the network.

6: A method of determining the end to end jitter experienced by a user of a device A communicating with a device B as defined in claim 4 and the path between A and B is determined by knowing the topology of the network.

7: A method of generating alarm, warning, error or ok conditions should the value of delay determined as in claims 1,3,5 or in any other manner exceed or be less than one or more thresholds which may or may not be set by the user.

8: A method of generating alarm, warning, error or ok conditions should the

value of jitter determined as in claims 2,4,6 or in any other manner exceed or be less than one or more thresholds which may or may not be set by the user.

9: A method of reporting the delays experienced in a path or in a set of paths or in any path in the network, where the delay is determined as in claims 1,3,5 or in any other manner.

10: A method of reporting the jitter experienced in a path or in a set of paths or in any path in the network, where the jitter is determined as in claims 2,4,6 or in any other manner.

11: A method of reporting the delays as in claim 9 where the N paths with greatest or least values of delays are reported.

12: A method of reporting the jitter as in claim 10 where the N paths with greatest or least values of jitter are reported.

13: A method of reporting and displaying the delays experienced in a path or in a set of paths or in any path in the network, where the delay is determined as in claims 1,3,5 or in any other manner, and where the delay values are indicated on a map of the topology by the delay for a path being written beside the path or the colour of the path chosen to indicate that the delay lies in a range of values corresponding to that colour.

14: A method of reporting and displaying the jitter experienced in a path or in a set of paths or in any path in the network, where the jitter is determined as in claims 2,4,6 or in any other manner, and where the jitter values are indicated on a map of the topology by the jitter for a path being written beside the path or the colour of the path chosen to indicate that the jitter lies in a range of values corresponding to that colour.

15: A method of determining the end to end delay experienced by users as in claim 5 and recording that information in a database and reporting that delay value to the user when the user requests this information either directly from a database or from a database via a website.

16: A method of determining the end to end jitter experienced by users as in claim 6 and recording that information in a database and reporting that delay value to the user when the user requests this information either directly from a database or from a database via a website.

17: A method of determining the end to end delay experienced by users as in claims 5 the alarm, warning, error or ok conditions of each such path as in claim 7 and recording this information and reporting it to the user when they interrogate the database for conditions on the path.

18: A method of determining the end to end jitter experienced by users as in claims 6 the alarm, warning, error or ok conditions of each such path as in claim 8 and recording this information and reporting it to the user when they interrogate the database for conditions on the path.

19: A method which records both the end to end delay as in claim 17 and the end to end jitter as in claim 18 and determines which path element contributed most to the delay or jitter and provides this information to a user who can interrogate the database either directly or indirectly or through a website.

20: A method as in claims 1,2,3,4,5 and 6 of determining the delay and/or jitter in a set of devices and paths and comparing the delays and/or jitters against thresholds to determine if a set of devices or paths meets the minimum criteria for a specified quality of service for voice over IP or other applications such as e-commerce.

21: A method as in claim 20 of determining the suitability of a set of devices and paths for a service and reporting the devices and paths which is replaced would then render the set of devices and paths suitable for that service, such a service being voice over IP or e-commerce.

22: A method as in claim 21 of determining the suitability of a set of devices and paths for a service and determining the devices and paths that are exceeding the threshold for delay and/or jitter and determining the sources of traffic that is causing such devices or paths to exceed thresholds and reporting this or these causes so that they can be removed or ameliorated rendering the set of devices and paths suitable for that service, such a service being voice over IP or e-commerce.

23: A method as in claims 20,21 or 22 where the set of devices and paths is one or more selected paths from one or more sources to one or more destinations, where the path or paths has been determined from the topology of the network.

24: A method as in claims 20,21,22 or 23 where the set of devices and paths includes portions or all of one or more networks which may be permanently or intermittently in communication.

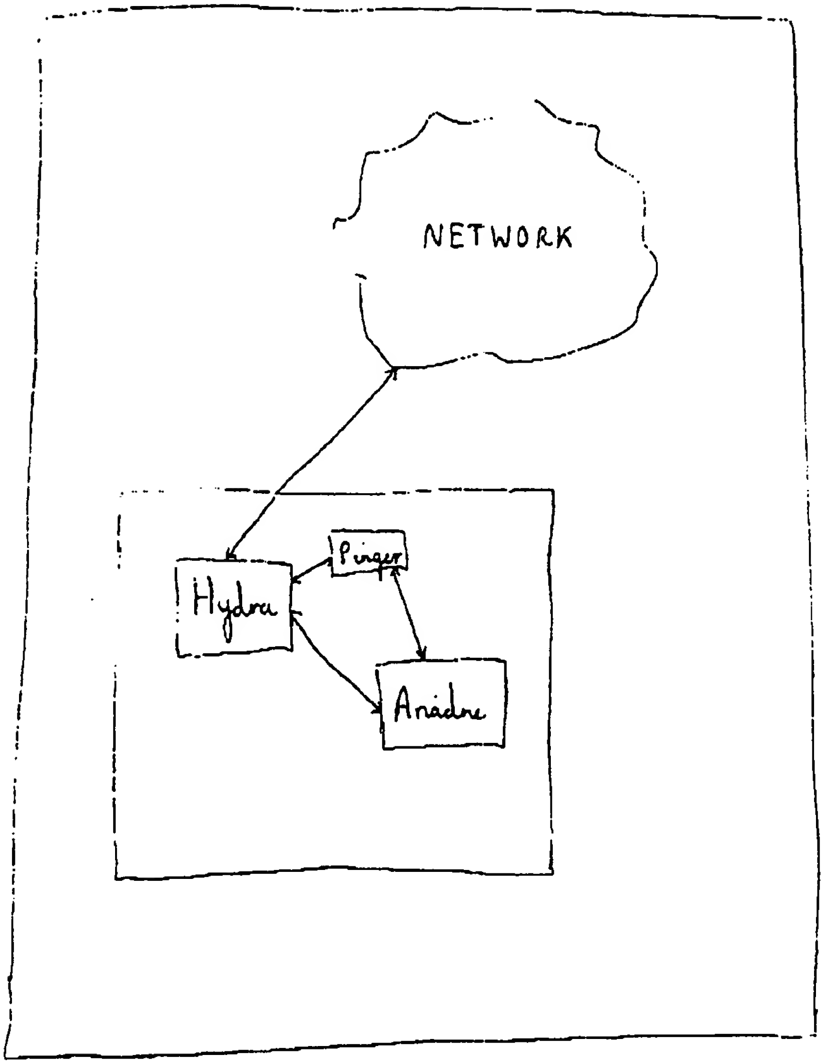

Figure 2:

Figure 1 :

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K - C - D
    |
    B - A
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